Visual Servoing using an Autonomous Quadcopter

Trinadh Venkata Swamy Naidu Venna

Advisors: Prof. Sarosh Patel, Prof. Tarek Sobh
Interdisciplinary Robotics Intelligent Sensing and Control Lab
School of Engineering ,University of Bridgeport

Project Aim

The goal of this project is to make autonomous quadcopter track and follow a given object in 3D space. We use visual servoing and adapted such that it can autonomously guide a quadcopter. In this poster we explain the technique and results

What is Visual Servoing?

Visual Servoing is a technique used in robotics to estimate the position and path of a tracked object using a fixed or moving camera. In this project we perform 3D visual servoing by a quadrotor with it's on board camera to track a given object during its flight and follow the objects path.

Image Processing

The video stream obtained from the quadcopter has standard rate of 30 fps. The size of each frame is 640X360, which consists of 230,400 pixels. Thresholding is an image processing technique where Intensity of a pixel $I_{i,j}$ is compared with a given constant value *T*. In this example we are using a green object. So, we apply thresholding only on the green layer and remove red and blue layers.

Image segmentation is then applied on the image to trace the area that has given set of qualities, such as object shape and minimum area. In this case we are looking for rectangular area. The result is shown in *Fig 3*. From this segmented image, we find the position, distance and orientation of the object.

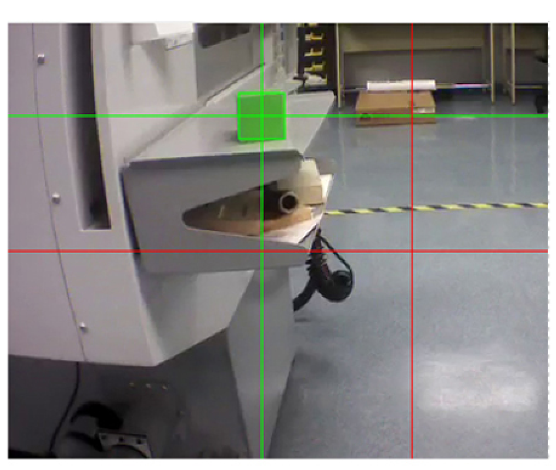

Fig 1. Original Image

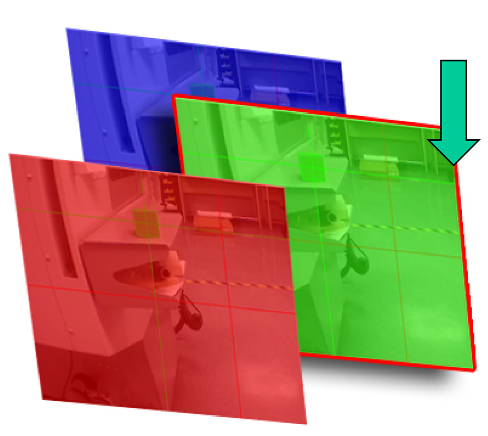

Fig 2. Green Thresholding

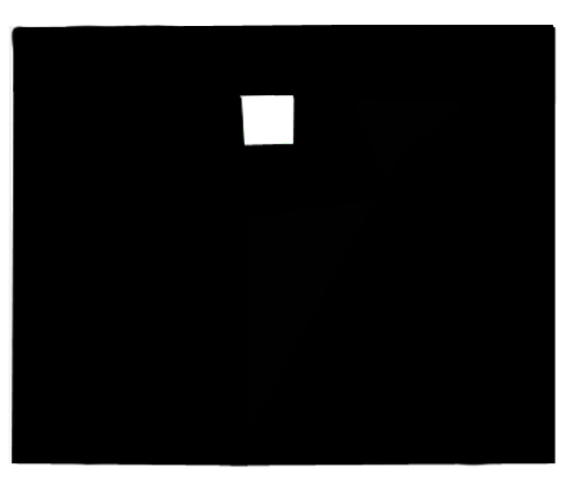

Fig 3. Image segmentation

Calculating object position parameters

It is ideal to keep the tracked object at the center of the image frame. Considering this, we measure the displacement of the object from the center of the frame F_c .

$$F_c = \left\{\frac{x_n}{2}, \frac{y_n}{2}\right\}$$

$where\ \ x_n\ is\ no.of\ pixels\ in\ x-axis,$

$y_n\ is\ no.of\ pixels\ in\ y-axis$

Center of the object can be found by taking the average of satisfied pixels position with respect to the video frame.

$$O_c = \left\{\frac{\sum Px_i}{Px_n}, \frac{\sum Py_i}{Py_n}\right\}$$

$where\ px, py\ are\ positions\ of\ the\ satisfied\ pixels\ in\ frame\ and$

$px_n,\ py_n$ *are count of satisfied pixels along x, y & axis.*

After the center of the object has been traced, we can now find the displacement from center of the video frame along x-axis and y-axis.

$\Delta x = O_c(x) - F_c(x);\ \Delta y = O_c(y) - F_c(y)$

if Δx > 1 ; drone flies left , Δx < 1 drone flies right

if Δy >1 ; drone lifts up, Δy < 1 drone descends

Thus quadcopter achieves 2D visual servoing.

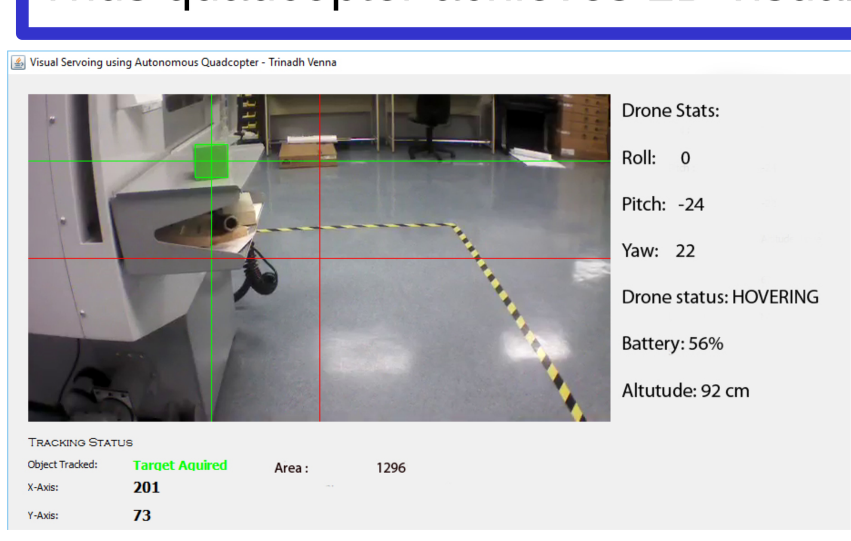

Fig 4

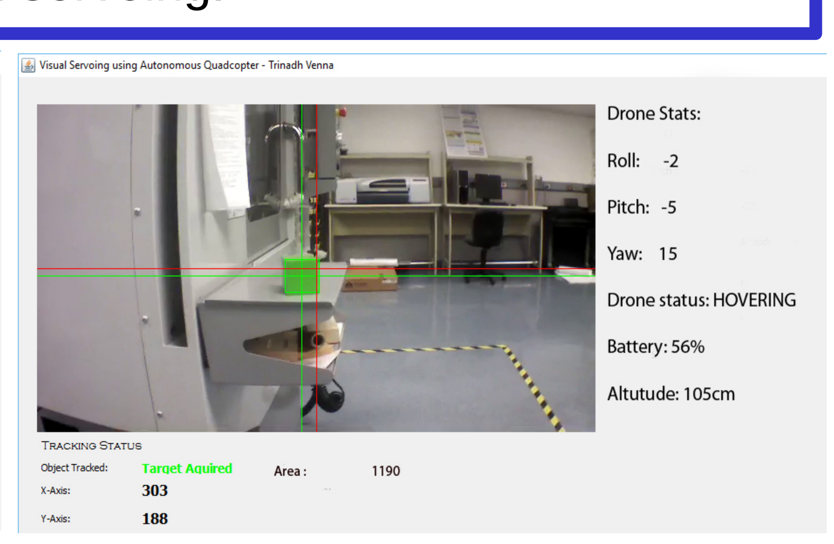

Fig 5

Fig 4 shows the initial location of the tracked object with respect to the video frame

Fig 5 shows the updated positon of the object after the quadcopter adjusts its flight

Finding the distance and orientation of the object

The area of the object is used to find the distance from the quadcopter. We know that the farther the distance, the smaller the object size and vice versa. The actual area of the object with respect to the video frame from an initial fixed distance is measured and taken as a constant A_k. The real time area can be calculated by multiplying height and width from the object shape after image segmentation, call it as A_o.

Then $\Delta z = \frac{A_0}{A_k}$, if Δz > 1, drone moves forward

Δz < 1 drone moves backward

Orientation of the object, is derived from the corners of the tracked object. For a spherical object, orientation cannot be derived, as it looks identical in any perspective. In our case, we consider a polygon object that has at least 3 corners and above. An easy example will be a square with 4 corners.

Consider the 4 corner pixels of square object as :$P_{lt}, P_{rt}, P_{lb}, P_{rb}$

If $y(P_{lt}) < y(P_{rt})$ *and* $x(P_{lt}) < x(P_{lb})$ *; object tilted to left*

$y(P_{lt}) > y(P_{rt})$ *and* $x(P_{lt}) > x(P_{lb})$ *; object tilted to right*

The above condition only tells us the direction but not the value. The following equation can be used to find the amount of roll/tilt of the object.

$$\theta_r = \tan^{-1}\frac{X_{rt}}{Y_{rt}} - \tan^{-1}\frac{h}{w};$$

$where\ h, w\ are\ height\ and\ width\ of\ object,$

$X_{rt}, Y_{rt}\ position\ parameters\ of\ top-right\ corner\ pixel$

If θ_r >1 , tilt to left, θ_r<1 tilt to right.

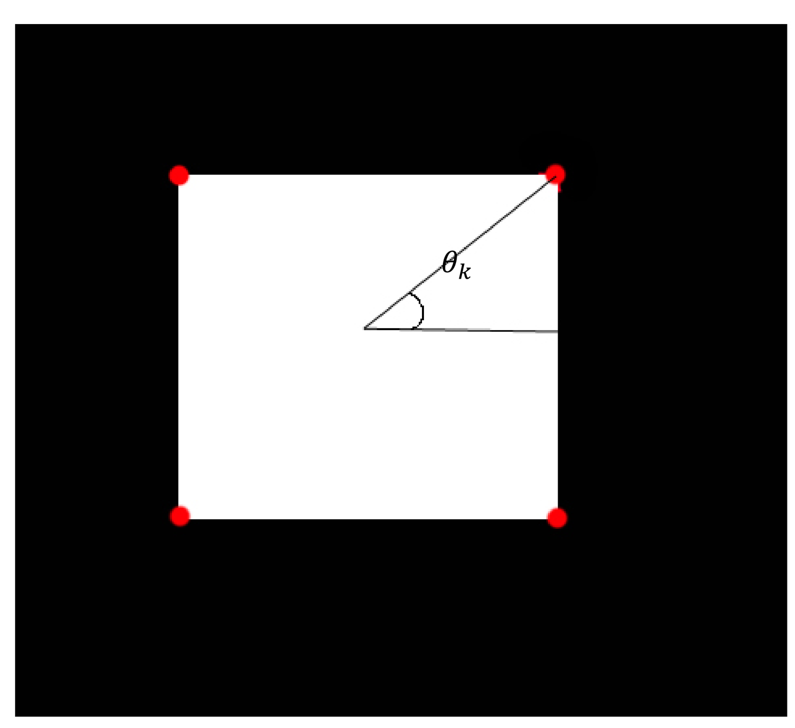

Fig 6. Initial position and constant angle

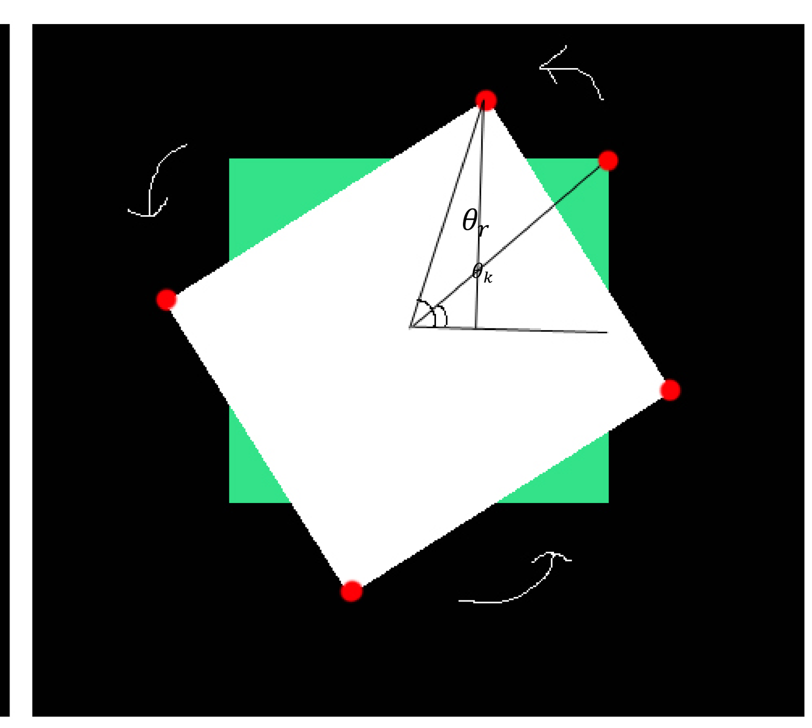

Fig 7. Orientation with respect to current frame

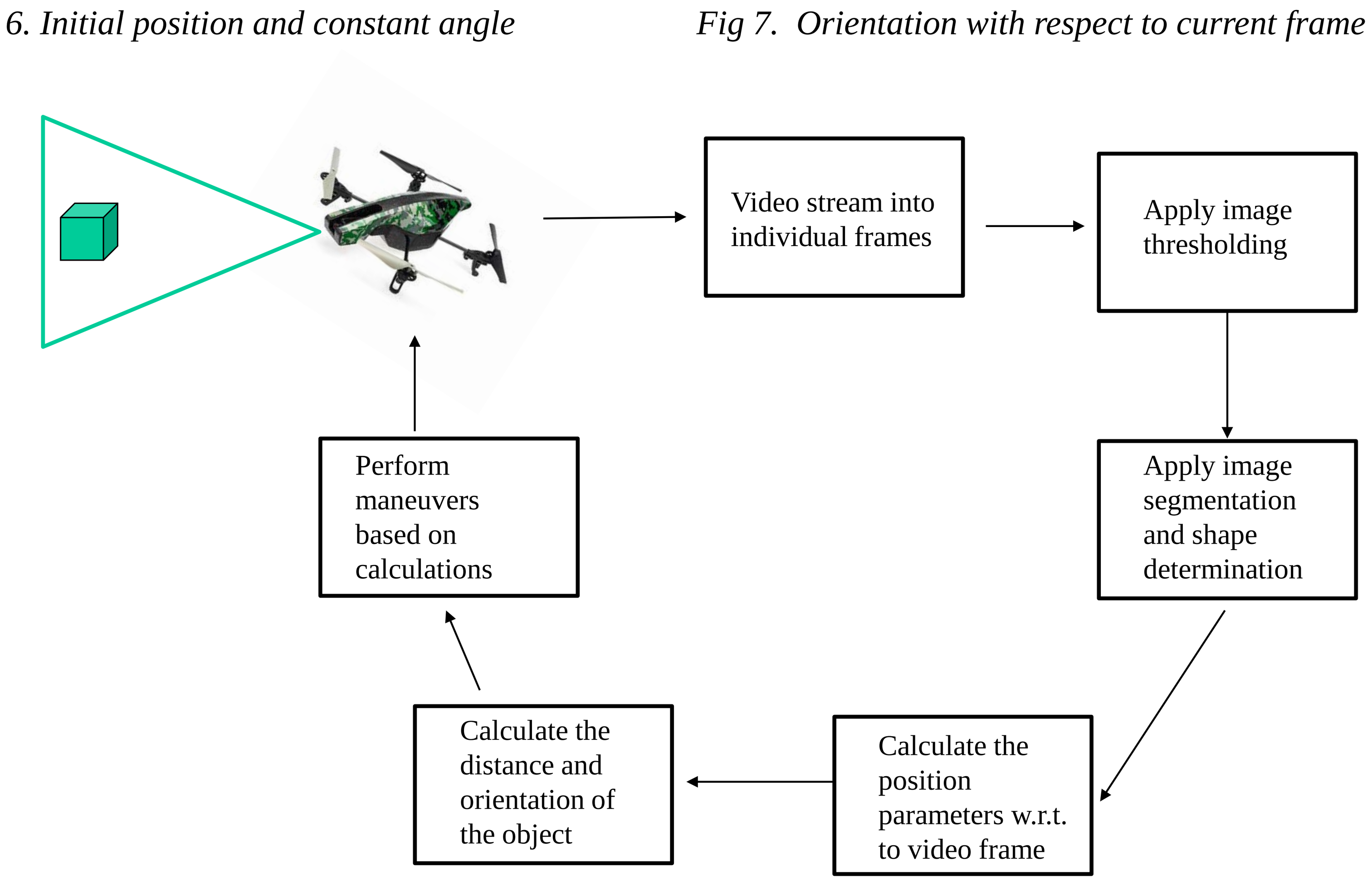

Fig 8. Concept flowchart

Results

The drone was able to autonomously track a given object in 3D space and follow it by determining the change in location, orientation and velocity of the object without human interception.

Future directions

In the research conducted, image processing techniques were processed in a centralized computer, this will be moved on board, using a micro controller to reduce latency while transmitting images. The object can be replaced with another drone that will be manually controlled and this quadcopter will be able to track it while its flying anywhere and doesn't require anyone's input.

Credits : *"Yet another drone" JAVA API and Framework by University if Hamburg*